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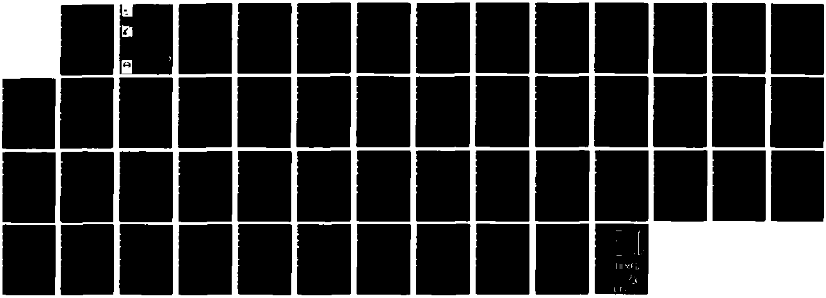

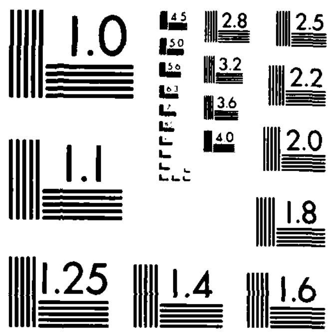

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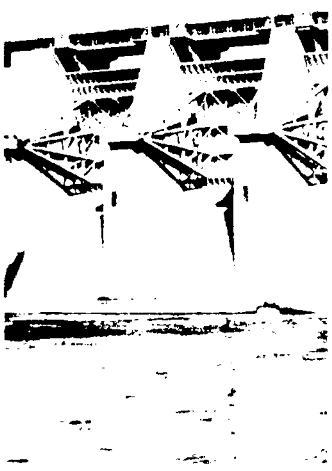

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EFFECTS OF WATER LEVEL CHANGES ON FISHES OF THE YAZOO RIVER BASIN, MISSISSIPPI

by

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>The effects of surface water withdrawal on habitat availability and quality were investigated in one lacustrine (Mossy Lake) and various river habitats in the Yazoo River Basin during the summer and fall of 1984 for the following fishes: bigmouth buffalo (Ictiobus cyprinellus), smallmouth buffalo (Ictiobus bubalus), common carp (Cyprinus carpio), channel catfish (Ictalurus punctatus), white crappie (Pomoxis annularis), and blacktail shiner (Notropis

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venustus). Water velocity, water depth, and instream cover types were determined at river sites where fishes were collected to develop utilization indexes for adult and juvenile life stages. Hydraulic models from the US Fish and Wildlife Service (USFWS) Instream Flow Incremental Methodology (IFIM) were coupled with the indexes to predict quantities of usable habitat for target species at various discharges. In large and medium-sized rivers it was determined that surface water removal would increase available habitat for species since current velocities would usually decrease and allow fish to utilize a greater percentage of the river. Small rivers would be adversely affected since diminished water levels would reduce cover availability and limit space for feeding and resting. It was determined that dissolved oxygen levels are adequate at normal flow but often decrease following heavy rain because of elevated biological oxygen demand. Based on regression equations developed from data collected on Mossy Lake, it was determined that withdrawing more than 3 to 4 feet of water from delta lakes would substantially reduce or completely eliminate the sport fishery.

Preface

This report describes a basinwide water needs study of fishes as part of an overall water demand study of the Yazoo River Basin being conducted by the US Army Engineer District, Vicksburg (LMK).

The study was completed by the Aquatic Habitat Group (AHG), Environmental Resources Division (ERD), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). The report was prepared by Mr. K. Jack Killgore and Dr. Andrew C. Miller, AHG. Dr. John Nestler and Ms. Toni Curtis, Environmental Research and Simulation Division, Dr. Barry Payne (AHG), and Mr. Scott Vowinkel (LMK) contributed to the conduct of this study. The report was prepared under the supervision of Dr. Thomas D. Wright, Chief, AHG; Dr. C. J. Kirby, Chief, ERD; and Dr. John Harrison, Chief, EL.

Director of WES was COL Allen F. Grum, USA. Technical Director was Dr. Robert W. Whalin.

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EFFECTS OF WATER LEVEL CHANGES ON FISHES OF THE YAZOO RIVER BASIN, MISSISSIPPI

Introduction

Background

1. Decreasing groundwater levels in the Yazoo River Basin indicate that future water demands cannot be fully met by the Mississippi River alluvial aquifer (US Army Corps of Engineers 1983). Surface water withdrawal from the Yazoo River and its tributaries has been considered as an alternative source of water for agriculture and industry. The highest water demands occur during the irrigation season from May-August (US Army Corps of Engineers 1983), while secondary demands for catfish farming and municipal and industrial purposes occur year-round, but primarily in April, September, and October. The US Army Engineer District Vicksburg (LMK) has concern over the effects of surface water removal on existing fish habitat in the Yazoo River Basin.

Purpose

2. The purpose of this study was to determine the effects of surface water removal on fish habitat in the Yazoo Delta during April to October. In addition, recommendations were made on flows that would enhance fish productivity.

Materials and Methods

Habitat Utilization Studies

3. Five sites were selected for detailed studies of fish habitat utilization. One site, Mossy Lake (ML), was chosen to represent a typical lake in the Yazoo River Basin. Mossy Lake covers 225 acres, has an average depth of 8 ft, and is surrounded by agricultural land. Lakes such as ML may become alternative sources of irrigation water when river stages are low. The remaining four sites were selected to represent the continuum of hydrologic conditions found in the Yazoo Basin.

4. The first riverine site chosen was in the Yazoo River at Yazoo City (YRYC) and represents fish habitat in mainstem, navigable river reaches. By virtue of being downstream of a flood control structure,

discharge at the YRYC site is only moderately influenced by rainfall. The next site chosen was in the Big Sunflower River at Anguilla (BSRA) and represents mainstem habitats found upstream of control structures. Flowing-water tributaries are reasonably represented by the third site which is located in the Big Sunflower River at Cypress Bend (BSRC). The last site chosen was in Short Creek near Yazoo City (SCYC) and represents a virtually lentic but still permanent tributary. This last habitat type is uncommon in the Yazoo Basin, but provides a potentially valuable source of food and cover for fish. A summary of hydraulic as well as geomorphic and instream cover conditions at the four riverine sites is provided in Table 1 with a list of other river reaches in the Yazoo Basin which are generally represented by each selected site.

5. Evaluation species were selected based on economic importance, trophic significance, and availability in the study areas. Suggestions on evaluation species were provided by the Mississippi Department of Wildlife Conservation and LMK. The riverine species used included the commercial fishes bigmouth buffalo (*Ictiobus cyprinellus*), smallmouth buffalo (*Ictiobus bubalus*) common carp (*Cyprinus carpio*), and channel catfish (*Ictalurus punctatus*). The white crappie (*Pomoxis annularis*) was selected because of its value as a sport fish. The blacktail shiner (*Notropis venustus*) represented a common riverine forage fish. Riverine species were grouped into juvenile and adult life stages using field determined length/weight relationships and from literature values for age and sexual maturity. The evaluation species used for Mossy Lake included largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macroshirus*), crappie (*Pomoxis* sp.), gar (*Lepisosteus* sp.), and shad (*Dorosoma* sp.). Habitat requirements for spawning were not considered in this study since water demands are low and water supply is high during the spring when spawning occurs for most fish species.

6. Site-specific habitat utilization was determined by measuring water depth, water velocity, and cover type at each location where an evaluation species was captured by electrofishing. Water depth was measured to the nearest 0.1 ft using either a metered rod or an electronic depth sounder. Water velocity was measured to the nearest 0.1 $ft \cdot sec^{-1}$ using a Marsh-McBirney model 201 current meter and probe. If total depth (TD) was less than or equal to 3.0 ft, then velocity was measured at 0.6 TD. If TD exceeded 3.0, then velocity was measured at both 0.2 and 0.8 TD. Cover was classified into one of four categories: no cover, logs or branches less than 12 in. diam., logs

greater than 12 in. diam., and rootwads or undercut banks. Fish were collected with a boat-mounted electrofishing unit using pulse AC at 300-400 volts and 3-6 amperes. Length and weight were recorded for each evaluation species that was caught. At each site, an approximately equal amount of time was spent fishing in each of the following eight possible habitat types (when all eight occurred): deep, fast-flowing, and without cover; deep, fast, and with cover; deep, slow-flowing, and without cover; deep, slow, and with cover; shallow, fast, without cover; shallow, fast, and with cover; shallow, slow, and without cover; and shallow, slow, and with cover. All data were gathered between July and October.

Habitat Availability Studies

7. In approximate parallel to the fish habitat studies, studies were conducted to determine the relationship between river discharge or stage and the amount of available fish habitat. We analyzed historic data on monthly discharges for April through October over a period of 17 years (Appendix I) for 18 gage stations spread over the entire Yazoo River Basin. Six gage stations were selected from a cluster analysis to represent the continuum of hydrologic conditions existing in the Basin (Table 2). April through October data were analyzed because that is the season of possible water withdrawal demand. In order to allow discharges to be transformed into river stage (a transformation often necessary due to different preferences of hydrologists) we provide the necessary regression equations in Appendix II.

8. In order to relate discharge to the amount of fish habitat, 1 transect was established over typical river cross sections at each representative gage station. Depth, velocity, and cover were measured at regular intervals of 5-10 feet (depending on cross-section distance) along each transect using methods described in paragraph 6. This approach to data acquisition is specially tailored to the input requirements of the IFIM as detailed elsewhere (Bovee 1981). These data were entered into a spatially arranged computer model that weights habitat availability at various flows by each fish species habitat utilization of depth, velocity, and cover. The output is expressed in weighted usable area (WUA) of fish habitat in ft^2 per 1000/linear feet of stream for a given discharge.

9. The IFIM assumes a positive linear relationship between standing crop of fishes and the amount of usable fish habitat. To provide estimates of fish standing crop as a function of WUA in the study area we analyzed data from

rotenone studies conducted in the 1960's and 1970's by the Mississippi Department of Wildlife Conservation. Much of the rotenone sampling was not conducted exactly where gages were located, but extrapolations were made according to the hydrologic, geomorphic, and cover similarities of the separately sampled river reaches. These data only approximate the relative standing crop of fishes at various discharges and are not considered absolute estimates of standing crop.

Water Quality Studies

10. Qualitative estimates on the effects of increased water temperatures and reduced dissolved oxygen levels were made for each species. Temperature and dissolved oxygen were measured at fish capture locations with a Mark IV water quality analyzer. An analysis of variance was used to determine if the evaluation species were collected at specific conditions of dissolved oxygen and temperature. If a significant difference occurred ($p < 0.05$) Tukey's studenized range test was used to identify preferences for certain ranges of temperature and dissolved oxygen.

Mossy Lake Studies

11. Regression equations were developed for the Mossy Lake evaluation species that predicted standing crop (pounds per acre) for a given water depth. The data used in this analysis came from rotenone studies conducted by the Mississippi Department of Wildlife Conservation and the Soil Conservation Service in 1959, 1969, and 1979. Although three data points are usually not sufficient to develop a regression equation, these were the only data available for which a prediction could be made on the impact of surface water withdrawal on delta lake fishes.

Results

Habitat Utilization Studies of Rivers in the Yazoo Basin

12. Habitat utilization of each evaluation species were first considered on a site-by-site basis, but an analysis of variance of fish habitat utilization between sites showed that, for riverine sites, intersite differences in habitat utilization did not exist. Therefore, the four riverine sites are considered together. Data for the bigmouth and smallmouth buffalo were combined since these two species utilized similar habitat conditions. Data for

Mossy Lake is considered separately in a latter section. Point locations of depth and velocity do not perfectly coincide with a captured fish's location. However, the habitat variable measurements reflect the conditions in the immediate vicinity of where the fish was located prior to being shocked. Therefore, measured values of depth and velocity were grouped into class intervals that reflect vicinity rather than point location. The class intervals were chosen according to the following empirical rule:

$$K = (3.3 * \text{Log } N) + 1$$

where

K = Number of class intervals

N = Total number of fish observations

A histogram of the number of adults and juveniles for each species caught per class interval were plotted. The grouped values were normalized to 0-1 by dividing the frequency of each class interval into the class interval with the maximum number of observations. A line was then fitted to each histogram. Cover was also normalized using the four cover types previously mentioned with each cover type being a discrete class. This approach resulted in an utilization index for each of the six species by life stage, and each of three variables (Appendix III). The Y axis ranges from 0-1, 0 being habitat not utilized by the species, and 1 being the habitat most utilized by the species, and the X axis representing the range of habitat conditions measured during the study.

13. The relative abundance of fishes collected in the study sites is summarized in Figure 1. The blacktail shiner was caught only in flowing water whereas the majority of the other species were taken where flow was nonexistent (Short Creek). This suggests that these species seem to prefer nonflowing water and thus any nonflowing tributary should be considered important habitat. The fewest number of fishes were caught at YRYC due to high velocities and the relatively inefficiency of the electroshocker to capture fishes in deep, fast flowing rivers. The fishes caught in YRYC, and to a lesser extent at BSRA, were usually found near the bank or in side channels associated with cover where they could escape high velocity water. Conversely, fishes were usually caught throughout the entire cross section at BSCB. All large bigmouth buffalo (i.e. > 500 mm total length) were captured in the deep holes at

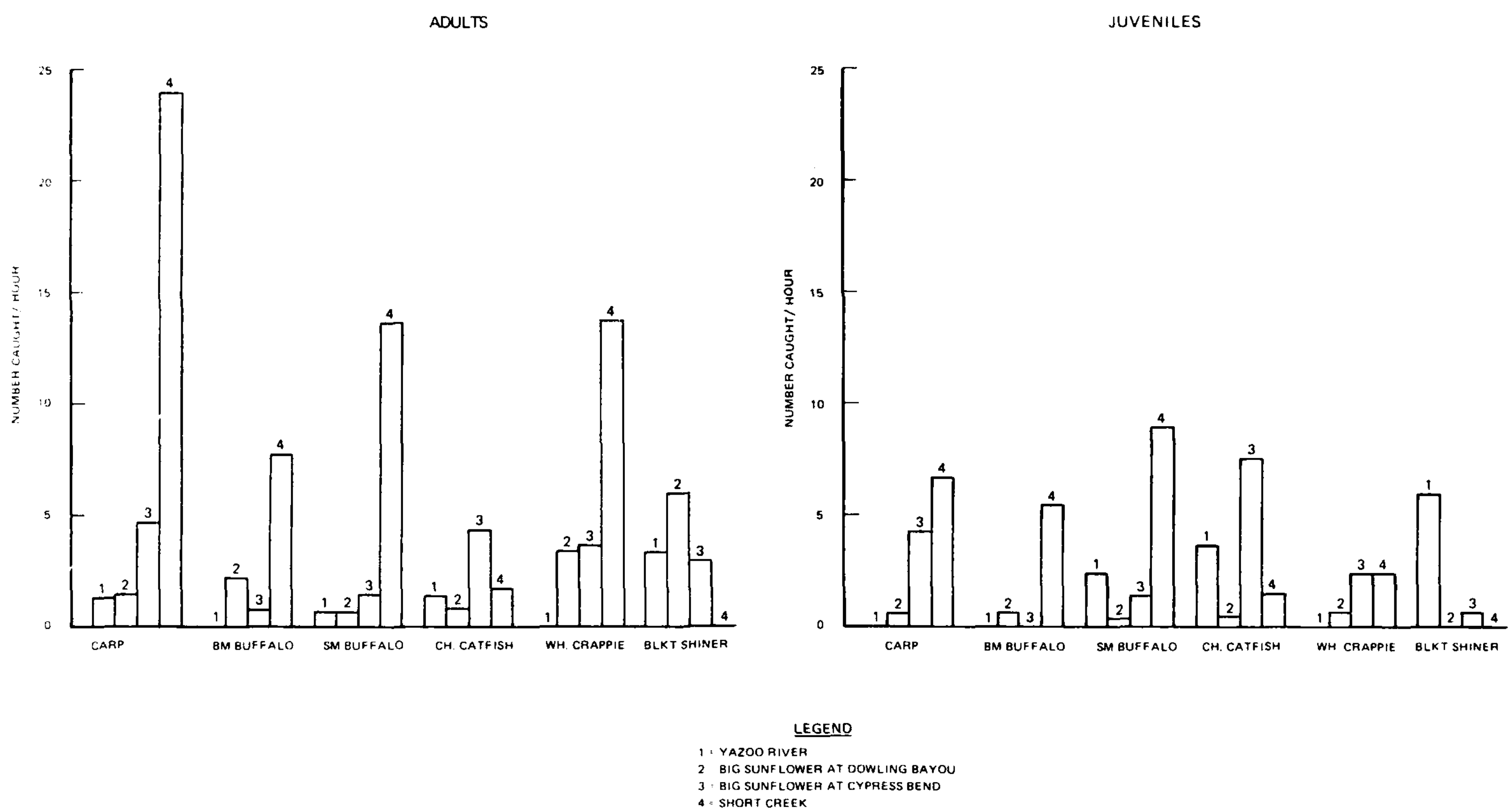

Figure 1: Number of Fish Captured per Hour of Electroshocking

bends in the Big Sunflower River between Anguilla and the Holly Bluff cutoff. These holes are uncommon and should be considered important habitat for adult bigmouth buffalo.

14. In general for riverine sites, high water velocities limited the microdistribution of all species. Blacktail Shiners were most tolerant and white crappie were least tolerant of high velocity. Instream cover was important to white crappie and channel catfish, but buffalo, carp, and blacktail shiners were relatively insensitive to cover. Adults usually exhibited greater tolerance for conditions of depth, velocity, and cover than did juveniles.

15. Condition factors were calculated for each species (except blacktail shiner) using the equation:

$$K = \frac{W * 10^6}{L^3}$$

where

W = Weight in grams

L = Total length

10^6 = Metric scaling constant

Fishes were separated into juveniles and adults based on total length and their K values compared with those in the literature (Table 3). The condition indices for fishes collected in the Yazoo Basin were similar to literature reported values of healthy fishes suggesting that an adequate food supply is available. Although the condition indices were relatively high for the white crappie when compared with values in the literature, many of these fish exhibited frayed fins and lesions indicating parasitic or bacterial stress.

Habitat Availability as a Function of Discharge

16. The quantity of habitat available (weighted usable area in ft^2/1000 linear ft) and standing crop for target fishes at discharges representing dry to above normal water conditions was estimated for 18 gage sites in the Yazoo Basin (Table 4). Since juveniles and adults were not separated in most of earlier studies of the Yazoo River Basin, the WUA used in the habitat-discharge relationships was an average of these two life stages. Usable

habitat was always less than the total area available at all discharges since high velocities, deep water, or lack of cover made certain areas unacceptable for fish. White crappie habitat was in the least supply while that of the adult blacktail shiner was usually the most abundant.

17. Sites on the Yazoo River and the Tallahatchie River near Swan Lake were characterized by high velocities (usually greater than 2 fps), deep water, and little available cover which resulted in low WUA values for all species. White crappie habitat was extremely limited. For all species in the Yazoo River the quantity of habitat peaked at low flows (4,000 - 5,000 cfs) then steadily declined at higher discharges. Except for the blacktail shiner, available habitat increased again at flows greater than 10,000 cfs because riparian vegetation was flooded and provided additional cover. For all species except the blacktail shiner the quantity of available habitat was highest at 7,000-8,000 cfs at the Tallahatchie River near Swan Lake. River banks were lower in the Tallahatchie River near Swan Lake so overbank flows occurred at intermediate as well as high flows.

18. The Big Sunflower River near Anguilla, Tallahatchie River near Lambert, Hickahala Creek near Senatobia, Steele Bayou near Onward, Coldwater River near Sarah, Big Sunflower River at Sunflower, and the Little Tallahatchie River at Etta provided more usable habitat than sites on the Yazoo River because water velocities and depths were lower which allowed fish to utilize a higher percentage of the river. Both species of buffalo, carp, and blacktail shiners had the largest amount of available habitat followed by channel catfish and white crappie. Habitat was highest at low flows (80-90% exceedance)* and declined at median flows. At extreme high flows shallow water and cover became more available resulting in an increase in habitat for most species.

19. Sites represented by Deer Creek at Hollandale were characterized by abundant cover, shallow (1 - 5 ft) water and low to moderate water velocities. For all species, available habitat was greatest at intermediate discharges. Even though more cover was available at high flows, this did not provide adequate refugia to offset the high water velocities. At low flows total area declined along with available habitat.

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* Exceedance value is the probability of a certain flow being equalled or exceeded.

20. Preferred flows were determined from the WUA-discharge relationships for each species. Preferred flows should maximize the available area (with specific attributes of depth, velocity, and cover) for the species with the least amount of habitat, while ensuring an adequate amount of high quality habitat for other species (Bovee 1981). Preferred flows should maintain or increase fish productivity. A preferred flow was determined separately for white crappie since this species occurs primarily in backwater or non-flowing habitat. The WUA-discharge relationships of the evaluation species at each representative site were arrayed into optimization matrix tables. For each flow, the species with the minimum WUA is recorded. The highest minimum recorded over the range of flows is considered the preferred flow.

21. Appendix IV presents the optimization matrix tables used to obtain the preferred flows in Table 5. Except for the Big Sunflower near Anguilla and the Tallahatchie River near Lambert, preferred flows were the same for all species (Table 5). The preferred flow for the Yazoo River sites was 3,000 cfs (90% exceedance value) and 7000 cfs (30-70% exceedance value depending on the month) at the Tallahatchie River near Swan Lake. The preferred flow for the bigmouth and smallmouth buffalo, carp, channel catfish, and blacktail shiner at the Big Sunflower River near Anguilla, Tallahatchie River near Lambert, and Hickahala Creek near Senatobia was 500 cfs (70-90% exceedance value) while the preferred flow for white crappie was 2,000 cfs at the Big Sunflower near Anguilla and 5,000 cfs at the Tallahatchie River near Lambert and Hickahala Creek near Senatobia. The preferred flow at sites represented by the Steele Bayou near Onward was 50 cfs (70-90% exceedance value) and 200 cfs (10-70% exceedance value) at sites represented by Deer Creek near Hollandale.

Impact Analysis of Surface Water Withdrawal in Yazoo Basin Rivers

22. Since flows resulting from surface water withdrawal were not available, Table 4 (Population Estimates and Available Habitat at Various Discharges for each Representative Gage Site), Appendix I (Monthly Flow Duration Tables of the 18 Gages in the Yazoo River Basin) and Table 5 (Preferred Flows at the 18 Gage Locations in the Yazoo Basin) were prepared in a manner that allows the user to calculate changes in the amount of fish habitat and standing crop for any surface water withdrawal proposal. For example,

approximately 2000 cfs is required to meet irrigation demands near Greenville during September. The discharge is currently 8600 cfs (50% exceedance value, see Appendix I) and would decrease to 6600 cfs if surface water were taken from the river. According to Table 4, this scenario will increase habitat for the two species of buffalo from 2400 WUA (27 lbs per mile) to 5400 WUA (61 lbs per mile). Thus, removing water from the Yazoo River would have a positive affect on buffalo productivity. Since the preferred flow for buffalo is 4,000 cfs (Table 5) additional water could be withdrawn from this site resulting in further increases in available fish habitat. Using this approach the environmental impacts of surface water withdrawal can be documented throughout the basin.

Water Quality Preferences of Fishes in Yazoo Basin Rivers

23. Table 6 summarizes the temperature and dissolved oxygen requirements for each species determined during this study. Although warmwater fishes are found in a wide range of temperatures, these data indicate preferences for each species. The carp and blacktail shiner were captured in warmer water ($\bar{X}$ = 28.0° C) than the other species indicating a tolerance for higher water temperatures. Both species of buffalo seemed to prefer relatively cooler water ($\bar{X}$ = 26.5° - 26.6°C) whereas the channel catfish and white crappie were usually found in intermediate water temperatures ($\bar{X}$ = 27.5° C). The dissolved oxygen levels were similar at all sites (Table 2) indicating no significant differences in dissolved oxygen requirements among species. An exception was the bigmouth buffalo which were found in areas exhibiting a mean dissolved oxygen level of 8.8 mg/ℓ whereas the other species utilized areas with significantly lower dissolved oxygen (i.e., $\bar{X}$ = 6.2-7.1 mg/ℓ).

Effects of Decreasing Water Depths on Fishes in Mossy Lake

24. Table 7 summarizes changes in standing crop of largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), crappie (*Pomoxis* sp.), gar (*Lepisosteus* sp.), and shad (*Dorosoma* sp.) when water depth is decreased. For all species, standing crop decreased as water depth decreased. At 4-5 ft, standing crop dropped to 0 pounds/acre, indicating that drastic changes in depth resulting from surface water withdrawal would severely stress or eliminate most fish species from delta lakes.

Discussion

25. Withdrawing water from the Yazoo River and most other large to medium sized tributaries will increase usable fish habitat. For example, a decrease from 10,000 to 4,000 cfs in the Yazoo River at Yazoo City increases usable habitat by 282%. High velocities currently prevent fishes from utilizing the entire river. Resting habitat is limited and only consists of areas along banks and behind instream objects that are used for velocity shelters. Feeding habitat is also limited because the velocities exceed the fish's ability to maintain adequate swimming speeds while foraging. For example, carp and suckers can swim at speeds up to 1.4 fps for an extended period of time (Bell 1973); however, mean water velocity in the Yazoo River is usually in excess of their capability. As a result, the availability of nonflowing tributaries for resting and feeding habitat is important to survival. These areas are highly utilized, but drastic drops in the water level could prevent access into them or they would become dewatered.

26. The relatively large quantities of usable physical habitat at all discharges for small and bigmouth buffalo, carp, and blacktail shiner suggest that they can adapt to changing environmental conditions. Matthews and Hill (1980) hypothesized that successful species either have evolved wide limits of tolerance for potentially stressful factors or change locations frequently to find optimal habitat. As long as food and dissolved oxygen are not limiting, our data suggest that these four species will continue to adapt and successfully inhabit the Yazoo River and its tributaries regardless of changing water levels. A recent study on the Yazoo Basin indicates that food is not a limiting factor (Howard, Needles, Tammen, and Bergendoff (HNTB) 1980) but dissolved oxygen levels are often low and could stress certain species. However, fish have the ability to change locations if dissolved oxygen or water temperature becomes stressful. The carp, smallmouth buffalo, and bigmouth buffalo frequently inhabit warm streams with temperature above 30°C (Meuwis and Huets 1957, McCrimmon 1968, Becker 1983). Carp have been reported to inhabit areas with dissolved oxygen below 5 mg/ℓ while the buffalo are less tolerant of dissolved oxygen concentrations below 5 mg/ℓ (McCrimmon 1968, Becker 1983).

27. The physical habitat of the white crappie and channel catfish in the Yazoo Basin rivers is limited at normal flows. Through resource partitioning, the white crappie and channel catfish could avoid competitive exclusion from

the more abundant species at higher flows. However, at lower flows all species will experience habitat overlap which could cause reduced food availability and convergence to similar microhabitat (MacArthur 1972, Matthews and Hill 1980). If cover is less available, the white crappie and channel catfish will be forced into less desirable habitat making feeding and predator avoidance more difficult. In addition, these species are less tolerant of low dissolved oxygen levels than carp and other rough fishes (Andrews et al. 1973, Carlson et al. 1974, Randolph and Clemens 1976, Stroud 1967). As a result, rough fishes that are more abundant and flexible in their habitat utilization could exclude channel catfish and white crappie from desirable habitat at reduced flows resulting in higher mortality.

28. The relationship between usable fish habitat (WUA) and discharge is based on the assumption that there is a positive linear relation between WUA and standing crop. As discussed earlier, warmwater fishes are highly adaptable to changing microhabitat and these relations may not be valid in all situations. Recent studies have shown that coldwater species are limited by usable habitat (Lewis 1969, White et al. 1976, Binns and Eiserman 1979); however, few studies have addressed this relationship for warmwater fishes. Orth and Maughan (1982) demonstrated that correlations between WUA and standing crop for several warmwater fishes occur during low flows, if they occur at all. During low flows habitat is limited in small rivers in the Yazoo Basin and thus this relationship may hold true for specialists such as the white crappie and channel catfish which have minimum space requirements for feeding and resting. At low flows reduced habitat availability could regulate fish density by limiting food availability and shelter from predators.

Conclusions and Recommendations

29. Large and medium sized rivers in the Yazoo Basin, including the Yazoo River at Yazoo City, Greenwood, and Belzoni, Tallahatchie River near Swan Lake and Lambert, Big Sunflower River near Anguilla, and those rivers represented by Steele Bayou near Onward, are characterized by a lack of cover with relatively deep, high velocity water. Surface water removal for purposes of irrigation at these sites will not have significant detrimental effects on bigmouth buffalo, smallmouth buffalo, common carp, channel catfish, white crappie, and blacktail shiner. At these rivers high discharge accompanied by

elevated water velocities and no substantial increase in amount of cover (i.e. no overbank flows) has negative effects on the quantity and quality of physical habitat.

30. At small tributaries to main stem rivers, represented by Deer Creek near Onward, optimum fish habitat is provided by intermediate discharge (200 cfs). Thus, withdrawing water from these areas will have detrimental effects to the fishery. At low discharge cover is limiting; at high discharge instream cover does not provide adequate refugia from high water velocities.

31. At low flows unobstructed access to nonflowing tributaries will be reduced or lost completely. This will have detrimental effects on fish populations since these tributaries provided valuable resting and feeding habitat for most fishes.

32. Condition or K-factors, a measure of robustness, was calculated for adult fishes captured during the study. These values were within the range of values reported in the literature for healthy fishes which indicates that fishes in the basin are not unduly stressed by lack of food, poor water quality conditions, or adverse physical habitat conditions.

33. There is little available habitat for white crappie in the Yazoo Delta Basin even though this is the most abundant sport fish (except for channel catfish). Lack of cover and high water velocities confine white crappie to isolated areas and management would probably do little to improve abundance. Although K-factors indicated that crappie were in good condition when compared with data in the literature, many that were collected during the summer of 1984 exhibited lesions and damaged fins indicating bacterial or parasite infections.

34. The preferred flows that appear in Table 5 should be used as a guideline to increase the quality and quantity of physical habitat for fishes in the Yazoo Basin.

35. It is recommended that water be withdrawn from the large and intermediate rivers as long as access is not prevented into the nonflowing tributaries (represented by Short Creek). Conversely, water should not be withdrawn from the small tributaries with flow, (represented by Deer Creek near Onward) since at low flows physical habitat is substantially reduced resulting in lower standing crops due to mortality or emigration.

36. Dissolved oxygen levels are presently adequate for existing fish species in the Yazoo Basin. It is postulated that at decreased flows dissolved

oxygen will not decline to stressful levels (i.e. below 4-5 mg/ℓ) because of aeration from water movement. However, increases in biological oxygen demand caused a major fish kill in the Big Sunflower and Yazoo Rivers and was probably caused by runoff of herbicides from adjacent cropland (Personal Communication, Mississippi Department of Natural Resources). Thus, allochthonous input from surrounding agricultural land could have a more pronounced effect on the dissolved oxygen levels than surface water withdrawal.

37. Withdrawing more than 3-4 ft of water from delta lakes would substantially reduce or completely eliminate the sport fishery.

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Table 1. Hydrologic, Geomorphic, and Instream Cover Conditions at the Four Riverine Sites Where Fish Utilization Studies Were Conducted in Relation to Other Rivers in the Yazoo Basin

Study Site	Habitat Conditions			Similar River Reaches
	Hydrologic	Geomorphic	Instream Cover	
Yazoo River at Yazoo City (YRYC)	High velocity (2-4 fps) that does not rapidly fluctuate due to rainfall.	Deep, wide, and straightened channel. Sloughing banks.	Isolated, semi-permanent willow stumps and overhanging willow branches.	Yazoo River and Tallahatchie River below flood control structure.
Big Sunflower River at Anguilla (BSRA)	High (1-2 fps) main but low (fps) side channel velocities. Rapid fluctuation due to rainfall.	Meandering channel. Pool-riffle sequence. Distinct main versus side channel areas.	Uncommon. Fallen timber and willow trees.	All wide river reaches upstream of flood control structures.
Big Sunflower River at Cypress Bend (BSRC)	Velocities range from 0-1 fps throughout cross section. Fluctuating discharge.	Small tributaries with meandering channels and little bank erosion.	Transient and permanent log jams. Overhanging riparian vegetation.	Small tributary of the Big Sunflower, Tallahatchie, and Yazoo Rivers.
Short Creek near Yazoo City (SCYC)	Velocities zero, except after rainfalls.	Steep sloughing banks, meandering channel.	Fallen trees and undercut banks.	Small, usually nonflowing tributaries of the Big Sunflower and Yazoo Rivers.

Table 2. Summary of Representative Gage Stations

Site Number	Representative Gage Site	Mean Flow From April-October (cfs)	Represented Gage Stations	Mean Flow From April-October (cfs)	Represented Fish *Study Sites*	Mean Flow From April-October (cfs)
1	Yazoo River Near Yazoo City	10,113	Yazoo River At Greenwood	11,340	Yazoo River Near Yazoo City	10,113
			Yazoo River At Belzoni	11,330		
2	Tallahatchie River Near Swan Lake	7,459	None	--	Yazoo River Near Yazoo City	10,113
3	Big Sunflower River Near Anguilla	4,552	None	--	Big Sunflower River Near Anguilla	4,552
4	Tallahatchie River Near Lambert	2,396	Hickahala Creek Near Senatobia	2,572	Big Sunflower River Near Anguilla	4,552
5	Steele Bayou Near Onward	1,195	Coldwater River Near Sarah	1,352	Big Sunflower River at Cypress Bend	876
			Big Sunflower River At Sunflower	845		
			Little Tallahatchie River at Etta	582		
6	Deer Creek Near Hollandale	122	Yalobusha River At Calhoun City	263	Big Sunflower River at Cypress Bend	876
			Yocona River Near Oxford	260		
			Shuna River At Bruce	211		
			Coldwater River Near Lewisburg	127		
			Big Sunflower River At Clarksdale	143		
			Clear Creek Near Oxford	13		

Table 3. Coefficient of Condition for Fishes of the Yazoo Basin

	Coefficient of Condition (K)					
	Yazoo Basin				Reported in Literature*	
Species	N	Mean	Standard Deviation	Range	Range of Means	Range of Individual Values
Bigmouth buffalo-all stages					1.39-1.66	1.08-2.80
Juveniles	12	1.58	0.15	1.26-1.81		
Adults	47	1.63	0.18	1.00-2.10		
Smallmouth buffalo-all stages					1.29-1.53	--
Juveniles	22	1.53	0.27	1.01-2.13		
Adults	33	1.51	0.13	1.25-1.81		
Carp-all stages					1.41-1.8	0.9-2.6
Juveniles	20	1.38	0.21	1.01-1.86		
Adults	82	1.38	0.16	0.93-1.79		
Channel catfish-all stages					0.75-1.12	0.5-1.33
Juveniles	24	1.04	0.26	0.60-1.60		
Adults	23	0.89	0.15	0.68-0.97		
White crappie-all stages					0.82-1.99	0.55-2.31
Juveniles	9	1.93	0.55	1.15-2.77		
Adults	48	1.51	0.31	0.73-2.33		

* Values are inclusive of all life stages. Data from Carlander (1969 and 1977).

Table 4. Population Estimates (lbs/mile) and Available Habitat at Various Discharges For Each Representative Gage Site

Site	Discharge (cfs)	Buffalo WUA*	Buffalo lbs/mile	Carp WUA	Carp lbs/mile	Channel Catfish WUA	Channel Catfish lbs/mile	White Crappie WUA	White Crappie lbs/mile	Blacktail Shiner WUA	Blacktail Shiner lbs/mile
Yazoo River At Yazoo City	3000	6754	76.6	4704	6.1	3653	1.0	363	0.004	10790	0.3
Site Represents:	4000	7344	83.3	8964	11.5	.309	2.0	739	0.009	14874	0.4
1) Yazoo River At Greenwood	5000	6650	75.5	7050	9.1	6400	1.8	370	0.004	12665	0.4
2) Yazoo River At Belzoni	6000	5791	65.7	5111	6.6	5208	1.4	143	0.002	10944	0.3
	7000	5300	60.1	4650	6.0	5250	1.5	130	0.001	10400	0.3
	8000	2224	25.2	3763	4.8	5223	1.4	78	0.001	9795	0.3
	9000	2450	27.8	2750	3.5	2975	0.8	80	0.001	8950	0.3
	10000	2393	27.2	2315	3.0	2419	0.7	228	0.003	8864	0.3
	15000	4660	52.9	4079	5.2	4366	1.2	461	0.006	7544	0.2
	20000	4204	47.7	684	0.9	267	0.07	6	0	1207	0.07
Tallahatchie River Near Swan Lake	3000	4045	45.9	4807	6.2	5551	1.5	231	0.003	11988	0.4
	4000	4071	46.2	4635	6.0	5230	1.5	276	0.003	12183	0.4
	5000	5155	58.5	7162	9.2	8630	2.4	788	0.01	10632	0.3
	6000	5536	62.8	6754	8.7	9416	2.6	870	0.01	7080	0.2
	7000	8181	92.8	13581	17.5	13860	3.9	1573	0.02	6949	0.2
	8000	7185	81.5	12424	16.0	14084	3.9	624	0.008	5961	0.2
	9000	7250	82.3	9800	12.6	12505	3.5	500	0.006	5100	0.2
	10000	7262	82.4	6025	7.7	4493	1.2	215	0.003	2420	0.07
	15000	2152	24.4	1246	1.6	1264	0.3	12	0	1041	0.03
	20000	931	10.6	349	0.4	300	0.08	0.2	0	499	0.01
Big Sunflower River Near Anguilla	500	99275	1897.0	49933	64.4	20045	9.5	6209	2.1	51560	1.9
	1000	60796	1162.0	26707	34.0	13451	6.4	4593	1.6	37075	1.3

(Continued)

* Average weighted usable area for all species in ft^2/1000 ft.

Table 4. (Continued)

Site	Discharge (cfs)	Buffalo WUA	Buffalo lbs/mile	Carp WUA	Carp lbs/mile	Channel Catfish WUA	Channel Catfish lbs/mile	White Crappie WUA	White Crappie lbs/mile	Blacktail Shiner WUA	Blacktail Shiner lbs/mile
Big Sunflower River Near Anguilla	2000	20095	384.0	16950	21.8	10212	4.8	7057	2.4	14403	0.5
	3000	16557	316.0	13804	17.7	8384	4.0	4619	1.6	6301	0.2
	4000	17633	337.0	17857	23.0	7104	3.4	4768	1.7	8140	0.3
	5000	17105	327.0	22931	29.5	18110	8.6	4161	1.4	10320	0.4
	8000	18834	360.0	18521	23.8	11888	5.6	3386	1.2	5719	0.2
	10000	17150	328.0	15053	19.4	12496	5.9	2651	0.9	6262	0.2
Tallahatchie River Near Lambert	400	6688	127.8	7263	9.3	8650	4.1	204	0.07	30823	1.1
Site Represents:	600	5688	108.7	6107	7.8	7131	3.4	407	0.1	20885	0.8
1) Hickahala Creek Near Senatobia	800	4891	93.5	6735	8.7	8437	4.0	431	0.1	16536	0.6
	1000	5386	103.0	8180	10.5	9838	4.6	936	0.3	13310	0.5
	5000	10450	199.7	11646	15.0	6708	3.2	2555	0.9	3349	0.1
	10000	7427	142.0	5605	7.2	3853	1.8	961	0.3	2149	0.1
Steele Bayou Near Onward	50	82261	204.6	54729	75.7	20815	23.2	54773	14.2	39643	1.9
Site Represents:	100	82874	206.2	50737	70.2	19174	21.4	34479	8.9	40879	2.0
1) Coldwater River Near Sarah	200	77582	193.0	43827	60.7	18291	20.4	10166	2.6	47688	2.3
2) Big Sunflower River At Sunflower	400	67568	168.1	36290	50.2	15443	17.2	8188	2.12	26395	1.3
3) Little Tallahatchie River At Etta	600	56899	141.5	25685	35.5	12339	13.8	1957	0.5	16844	0.8
	800	44263	110.1	18136	25.1	9174	10.2	1076	0.3	11772	0.6
	1000	33497	83.3	12715	17.6	6089	6.8	676	0.2	7680	0.4
	2000	6944	17.3	4995	6.9	3782	4.2	332	0.1	2034	0.1
	3000	3535	8.7	3419	4.7	1709	1.9	124	0.03	710	0.03
	5000	2814	7.0	1107	1.5	433	0.5	0	0	470	0.02

(Continued)

Table 4. (Concluded)

Site	Discharge (cfs)	Buffalo WUA	Buffalo lbs/mile	Carp WUA	Carp lbs/mile	Channel Catfish WUA	Channel Catfish lbs/mile	White Crappie WUA	White Crappie lbs/mile	Blacktail Shiner WUA	Blacktail Shiner lbs/mile
Deer Creek Near Hollandale	10	5230	9.7	3554	8.6	4429	8.9	404	0.1	12095	1.0
Site Represents:	50	8929	16.6	11615	28.2	14016	28.1	881	0.2	23326	2.0
1) Yalobusha River At Calhoun City	100	13537	25.1	16836	40.9	18857	37.8	1997	0.6	32303	2.7
2) Yocona River Near Oxford	200	30239	56.1	30265	73.5	26377	52.8	9205	2.6	27644	2.3
3) Skuna River At Bruce	400	30335	56.3	19484	47.3	6634	13.3	3091	0.9	7748	0.6
4) Coldwater River Near Lewisburg	600	20516	38.1	7472	18.1	1976	3.9	1940	0.5	1988	0.2
5) Big Sunflower River At Clarksdale	800	13314	24.7	4111	10.0	1124	2.2	955	0.3	771	0.1
6) Clear Creek Near Oxford	1000	9920	18.4	2837	6.9	524	1.0	603	0.2	374	0.03

Table 5. Preferred Flows* at the 18 Gage Locations in the Yazoo Basin

Site	Species	Flow (cfs)	Standing Crop (lbs/mile)
Yazoo River at Greenwood	All Species**	4,000	97.2
Yazoo River at Belzoni			
Yazoo River at Yazoo City			
Tallahatchie River near Swan Lake	All Species	7,000	114.4
Big Sunflower River near Anguilla	Buffalo, Carp, Channel Catfish, Blacktail Shiner	500	1972.8
	White Crappie	5,000	0.9
Tallahatchie River near Lambert	Buffalo, Carp, Channel Catfish, Blacktail Shiner	400	142.3
Hickahala Creek near Senatobia			
	White Crappie	5,000	0.9
Coldwater River near Sarah	All Species	50	319.6
Steele Bayou near Onward			
Big Sunflower River at Sunflower			
Little Tallahatchie River at Etta			
Yalobusha River at Calhoun City	All Species	200	187.3
Yocona River near Oxford			
Skuna River at Bruce			
Coldwater River near Lewisburg			
Big Sunflower at Clarksdale			
Deer Creek near Hollandale			
Clear Creek near Oxford			

* Preferred flows determined from optimization matrix tables shown in Appendix IV and defined in paragraph 20.

** All species include Buffalo, Carp, Channel Catfish, Blacktail Shiner, and White Crappie.

Table 6. Comparison of Preferred Temperature and Dissolved Oxygen Values Between Species in the Yazoo Basin

Species	N	Temperature (°C) Mean	Temperature (°C) Standard Deviation	Temperature (°C) Species Whose Means are Significantly Different ($P < 0.05$)	Dissolved Oxygen (mg/ℓ) Mean	Dissolved Oxygen (mg/ℓ) Standard Deviation	Dissolved Oxygen (mg/ℓ) Species Whose Means are Significantly Different ($P < 0.05$)
Bigmouth buffalo	51	26.6	1.2	Blacktail shiner Carp	8.8	1.9	All species
Smallmouth buffalo	51	26.5	1.4	Blacktail shiner Carp	7.1	1.8	Bigmouth buffalo
Carp	106	28.0	2.5	Bigmouth buffalo Smallmouth buffalo	6.6	1.5	Bigmouth buffalo
Channel catfish	57	27.5	2.2	None	6.2	1.1	Bigmouth buffalo
White crappie	51	27.5	2.2	None	6.6	1.3	Bigmouth buffalo
Blacktail shiner	59	28.0	2.4	Bigmouth buffalo Smallmouth buffalo	6.5	1.3	Bigmouth buffalo

Table 7. Predicted Standing Crop For Selected Species at Seven Water Depths for Mossy Lake

Species	Regression Equation	R^2	Standing Crop (lbs/acre) at Indicated Average Depth (ft)						
			8	7	6	5	4	3	2
Micropterus salmoides	lbs/acre = depth (6.32) - 26.2	0.61	24.4	18.1	11.8	5.4	0	0	0
Lepomis macrochirus	lbs/acre = depth (29.6) - 108.7	0.41	127.9	98.3	68.7	39.2	9.6	0	0
Pomoxis sp.	lbs/acre = depth (10.1) - 47.6	0.84	33.6	23.4	13.3	3.2	0	0	0
Lepisosteus sp.	lbs/acre = depth (9.32) - 49.5	0.99	25.0	15.7	6.4	0	0	0	0
Dorosoma sp.	lbs/acre = depth (91.6) - 445.7	0.85	286.9	195.3	103.7	12.2	0	0	0

Appendix I: Monthly Flow Duration Tables of the 18 Gages in the Yazoo River Basin

Historic Flows at 18 Gages in the Yazoo River Basin Presented as Flow Duration Values

	Discharge (cfs)						
	April	May	June	July	August	September	October
Yazoo River At Greenwood							
*P10	26600	23700	21100	16100	15300	13700	13600
P30	18700	18400	16600	11800	12300	10900	10600
P50	17100	17500	14500	9900	9300	8600	8400
P70	11800	12100	9900	8100	8500	7400	7100
P90	6800	6200	7800	5600	4700	5100	5700
Mean	15284	14675	11900	10186	9641	8840	8809
Yazoo River At Belzoni							
P10	24500	23000	22100	15300	13200	13100	12900
P30	20400	18100	16000	12100	11800	10900	11000
P50	17300	14700	10500	9500	9800	8300	8900
P70	11400	10100	9500	8900	7700	7700	7700
P90	6200	8500	6300	6500	4700	5800	6300
Mean	15637	14666	11867	10071	9398	8726	9104
Yazoo River At Yazoo City							
P10	21800	21500	18900	12600	11200	10500	10600
P30	18000	16800	13200	9900	10100	9400	9500
P50	15500	14100	9500	8100	8400	7100	8100
P70	11500	10700	7700	7300	6400	6300	6400
P90	6900	9600	6200	6100	4700	5100	5700
Mean	14454	14253	10430	8701	7975	7440	7780

(Continued)

* P10 - P90 indicates the discharge that is equalled or exceeded a given percentage of the time.

Historic Flows (Continued)

	Discharge (cfs)						
	April	May	June	July	August	September	October
Tallahatchie River Near Swan Lake							
P10	19500	17600	16900	10300	9900	8670	9000
P30	14000	13000	11500	7900	7700	6700	6900
P50	12100	10700	10200	6700	6900	5300	5900
P70	8200	5400	7500	5200	4900	4800	4800
P90	6400	3800	4900	3600	3200	3800	4300
Mean	10050	9938	7776	6596	6291	5643	5922
Big Sunflower River Near Anguilla							
P10	29000	28500	22000	3700	2900	1600	1500
P30	15600	13100	4000	1600	1290	900	850
P50	10200	6100	2100	1290	942	790	740
P70	3100	4700	980	960	880	720	690
P90	1450	1900	830	730	730	700	600
Mean	11607	10462	4878	1619	1250	919	846
Hickahala Creek Near Senatobia							
P10	11000	11500	13000	11500	9050	9000	8700
P30	9500	3100	3600	990	2500	2200	1100
P50	1500	1700	1050	690	540	540	570
P70	690	630	650	290	290	310	200
P90	250	350	190	100	150	120	110
Mean	3206	3088	2188	2531	2515	2331	2119

(Continued)

Historic Flows (Continued)

	Discharge (cfs)						
	April	May	June	July	August	September	October
Tallahatchie River Near Lambert							
P10	8600	8500	5100	2900	2600	2200	2000
P30	6600	5600	2900	2100	1900	1190	1350
P50	4700	4800	1950	1700	1700	1050	1150
P70	2700	3250	1650	950	1100	950	1070
P90	1300	1300	1100	560	460	575	670
Mean	4563	4358	2476	1566	1476	1153	1179
Coldwater River Near Sarah							
P10	3900	3500	2200	1975	1850	2200	1200
P30	3350	2850	1600	1675	1600	1000	880
P50	2700	2350	1250	870	1150	750	780
P70	1300	1600	1020	570	770	500	650
P90	800	550	350	350	260	350	400
Mean	2290	2128	1244	1019	1084	869	764
Steele Bayou Near Onward							
P10	7200	7500	8000	650	750	900	200
P30	3700	3800	2100	300	170	100	170
P50	1700	2100	1900	170	110	40	40
P70	1150	900	1350	110	60	30	20
P90	725	300	1150	45	40	22	10
Mean	3034	2920	834	217	180	175	82

(Continued)

Historic Flows (Continued)

	Discharge (cfs)						
	April	May	June	July	August	September	October
Big Sunflower River at Sunflower							
P10	4300	3000	1900	1300	1300	1100	425
P30	2700	2500	1050	700	470	350	300
P50	1450	1500	575	475	380	220	140
P70	640	1100	300	210	260	160	115
P90	400	300	200	140	180	130	100
Mean	1824	1566	946	535	487	358	196
Littie Tallahatchie River At Etta							
P10	3900	2300	1300	750	600	400	300
P30	2900	1800	450	330	210	260	200
P50	1200	1500	250	150	80	75	140
P70	600	320	145	95	55	45	50
P90	325	240	95	60	45	30	25
Mean	1668	1187	420	263	199	197	137
Yalobusha River At Calhoun City							
P10	2300	1000	350	300	175	250	400
P30	1500	660	170	80	50	80	40
P50	870	375	60	47	25	35	12
P70	350	100	20	20	14	8	5
P90	125	50	10	10	6	5	3
Mean	942	436	139	110	51	90	77

(Continued)

Historic Flows (Continued)

	Discharge (cfs)						
	April	May	June	July	August	September	October
Yocona River Near Oxford							
P10	1690	1225	650	315	225	300	165
P30	1340	860	220	125	70	80	80
P50	650	425	100	60	55	47	60
P70	320	150	55	40	30	40	25
P90	175	85	40	25	22	20	17
Mean	764	513	192	105	79	103	62
Skuna River Near Bruce							
P10	1560	1050	650	200	230	200	125
P30	1360	400	130	95	50	75	35
P50	600	300	55	45	20	40	25
P70	230	95	27	18	15	14	10
P90	100	50	12	10	9	9	7
Mean	723	345	162	72	55	81	44
Coldwater River Near Lewisburg							
P10	450	400	200	350	260	260	320
P30	290	170	160	165	170	155	170
P50	180	75	100	125	140	150	150
P70	60	25	40	35	50	70	115
P90	16	10	30	10	8	30	30
Mean	179	118	96	114	111	111	141

(Continued)

Historic Flows (Concluded)

	Discharge (cfs)						
	April	May	June	July	August	September	October
Big Sunflower River At Clarksdale							
P10	550	480	350	130	150	140	150
P30	250	280	150	105	100	100	100
P50	190	190	105	92	87	87	87
P70	160	135	95	87	84	75	75
P90	110	87	90	85	75	71	70
Mean	239	224	159	99	99	93	93
Deer Creek Near Hollandale							
P10	675	500	350	175	120	130	95
P30	290	220	175	95	90	80	80
P50	175	160	90	70	70	63	65
P70	110	95	65	50	40	50	45
P90	75	60	35	10	15	25	15
Mean	239	208	133	76	64	65	58
Clear Creek Near Oxford							
P10	40	55	25	30	11	20	10
P30	30	15	11	13	9	9	9
P50	20	13	8	10	7	8	8
P70	11	10	7	8	7	7	7
P90	9	8	7	7	6	7	6
Mean	21	20	11	12	8	11	8

Appendix II: Regression Equations to Predict Discharge from Stage or Stage from Discharge for 18 Gages in the Yazoo Basin

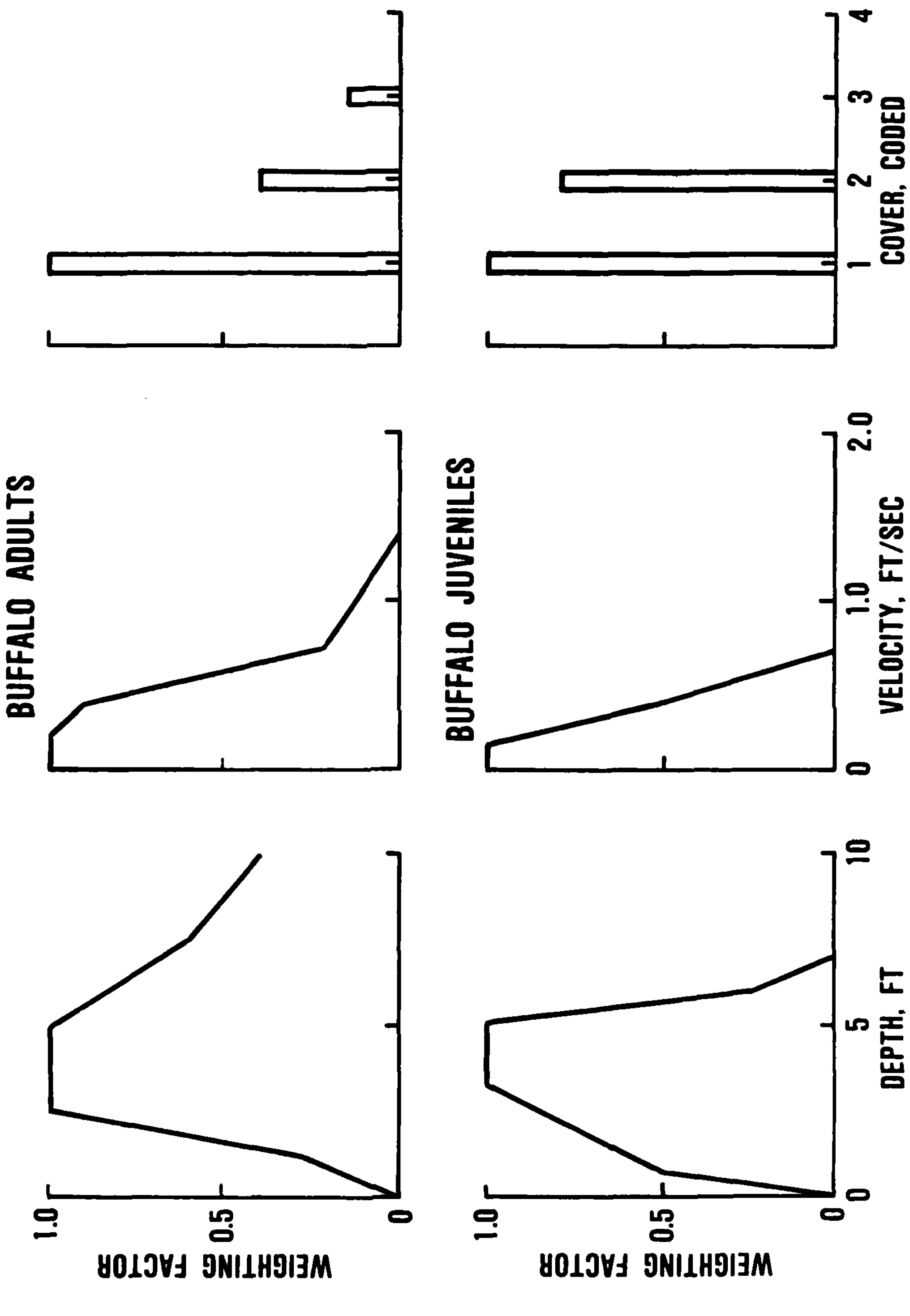
Regression Equations to Predict Discharge from Stage and Stage from Discharge for Gages in the Yazoo Basin

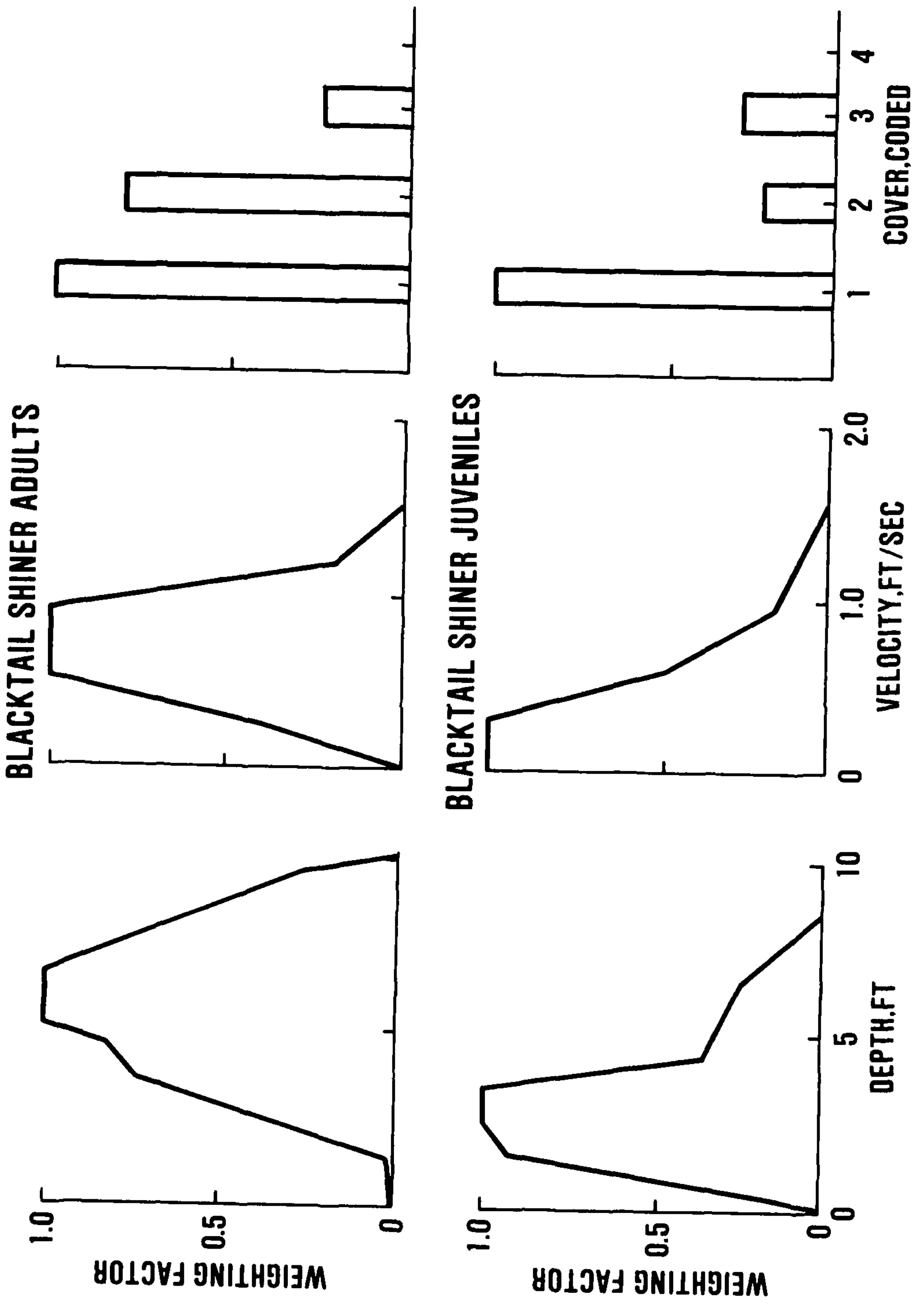
Gage Site	Regression Equations		
Yazoo River At Greenwood	Discharge* = Stage** (1124.7) - 11508.4	R^2 = 0.98	Stage = Discharge (0.001) + 10.47
Yazoo River At Belzoni	Discharge = Stage (889.6) - 4570.6	R^2 = 0.99	Stage = Discharge (0.001) + 5.28
Yazoo River At Yazoo City	Discharge = Stage (646.7) - 421.5	R^2 = 0.99	Stage = Discharge (0.001) + 0.67
Tallahatchie River Near Swan Lake	Discharge = Stage (737.5) - 4618.8	R^2 = 0.94	Stage = Discharge (0.001) + 6.86
Big Sunflower River Near Anguilla	Discharge = Stage (883.2) - 21369.3	R^2 = 0.94	Stage = Discharge (0.001) + 24.74
Hickahala Creek Near Senatobia	Discharge = Stage (1854.9) - 13219.4	R^2 = 0.86	Stage = Discharge (0.0005) + 7.43
Tallahatchie River Near Lambert	Discharge = Stage (462.3) - 5050.5	R^2 = 0.90	Stage = Discharge (0.002) + 11.83
Coldwater River Near Sarah	Discharge = Stage (381.3) - 514.3	R^2 = 0.97	Stage = Discharge (0.003) + 1.47
Steele Bayou Near Onward	Discharge = Stage (344.9) - 732.7	R^2 = 0.96	Stage = Discharge (0.003) + 2.37
Big Sunflower River At Sunflower	Discharge = Stage (233.3) - 921.5	R^2 = 0.95	Stage = Discharge (0.0041) + 4.47
Little Tallahatchie River At Etta	Discharge = Stage (375.5) - 3656.4	R^2 = 0.98	Stage = Discharge (0.003) + 9.83
Yalobusha River At Calhoun City	Discharge = Stage (292.2) - 2316.3	R^2 = 0.99	Stage = Discharge (0.003) + 7.95
Yocona River Near Oxford	Discharge = Stage (216.9) - 560.4	R^2 = 0.97	Stage = Discharge (0.004) + 2.68
Skuna River At Bruce	Discharge = Stage (239.1) - 1157.9	R^2 = 0.94	Stage = Discharge (0.004) + 4.98
Coldwater River Near Lewisburg	Discharge = Stage (73.5) - 120.6	R^2 = 0.96	Stage = Discharge (0.013) + 1.75
Big Sunflower River At Clarksdale	Discharge = Stage (96.1) - 297.1	R^2 = 0.99	Stage = Discharge (0.010) + 3.13
Deer Creek Near Hollandale	Discharge = Stage (64.6) - 291.2	R^2 = 0.96	Stage = Discharge (0.015) + 4.72
Clear Creek Near Oxford	Discharge = Stage (174.5) - 435.5	R^2 = 0.95	Stage = Discharge (0.005) + 2.54

* Discharge (cfs).

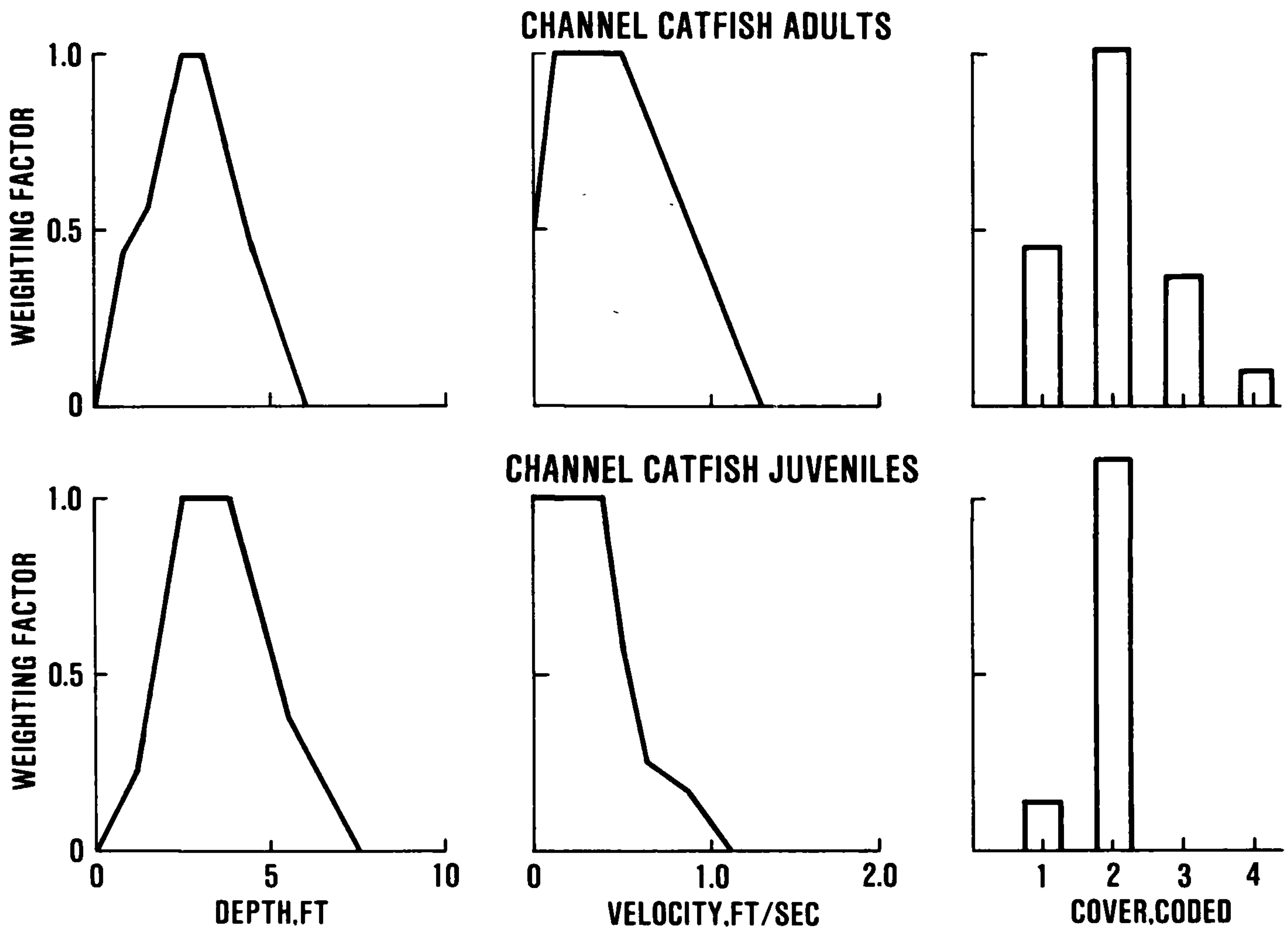
** Stage (ft).

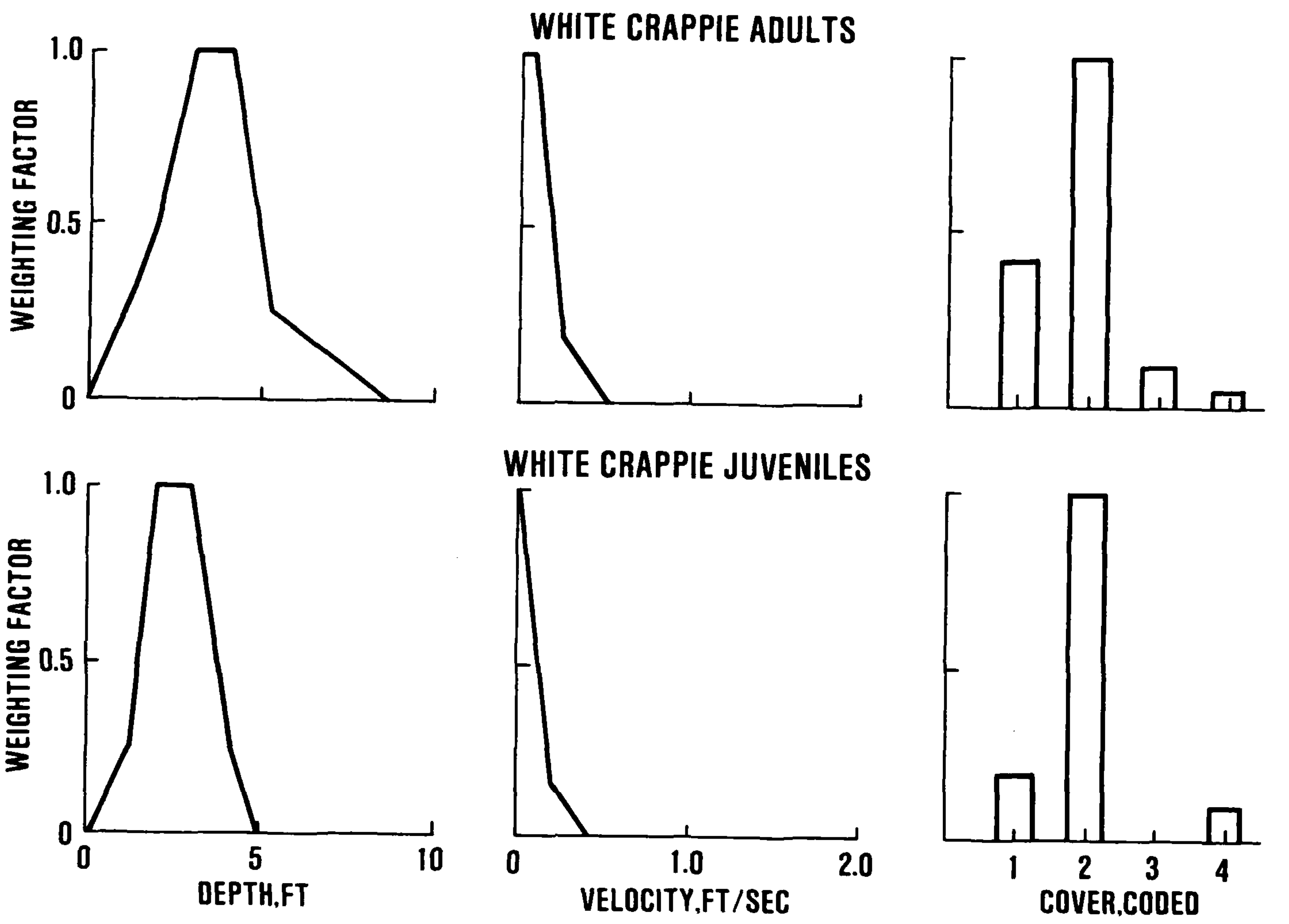
Appendix III: Utilization Index Curves for Depth, Velocity, and Cover Determined from Field Observations in the Yazoo River Basin

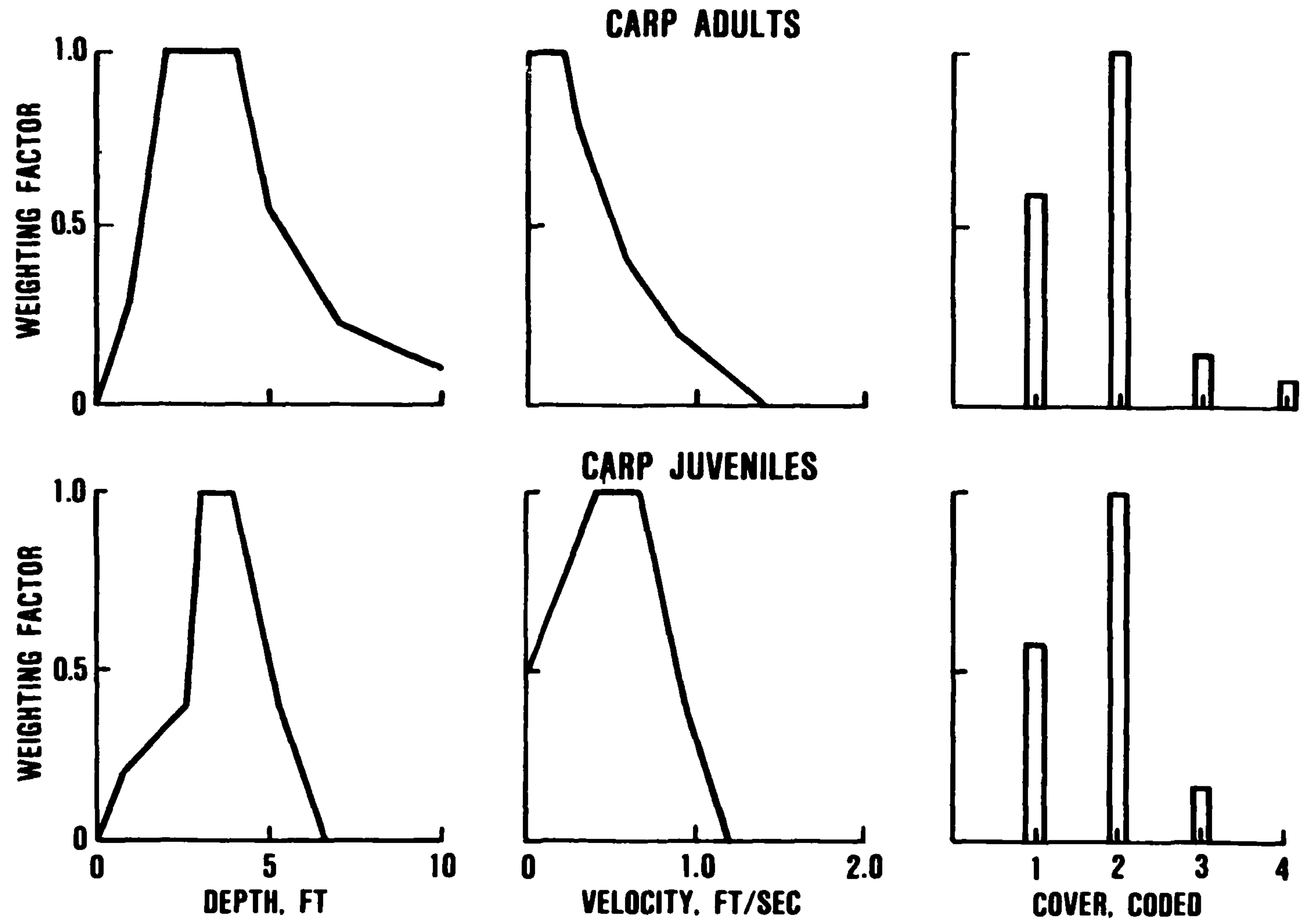

BUFFALO ADULTS
BUFFALO JUVENILES
WEIGHTING FACTOR
1.0
0.5
0
DEPTH, FT
0
5
10
VELOCITY, FT/SEC
0
1.0
2.0
COVER, CODED
1
2
3
4



BLACKTAIL SHINER ADULTS
BLACKTAIL SHINER JUVENILES
WEIGHTING FACTOR
WEIGHTING FACTOR
1.0
0.5
0
1.0
0.5
0
0
5
10
DEPTH,FT
0
1.0
2.0
VELOCITY,FT/SEC
1
2
3
4
COVER,CODED


CHANNEL CATFISH ADULTS
CHANNEL CATFISH JUVENILES
WEIGHTING FACTOR
WEIGHTING FACTOR
1.0
0.5
0
0
5
10
DEPTH,FT
0
1.0
2.0
VELOCITY,FT/SEC
1
2
3
4
COVER,CODED


WHITE CRAPPIE ADULTS
WHITE CRAPPIE JUVENILES
WEIGHTING FACTOR
1.0
0.5
0
5
10
DEPTH,FT
1.0
2.0
VELOCITY,FT/SEC
1
2
3
4
COVER,CODED


CARP ADULTS
CARP JUVENILES
WEIGHTING FACTOR
1.0
0.5
0
0
5
10
DEPTH, FT
0
1.0
2.0
VELOCITY, FT/SEC
1
2
3
4
COVER, CODED

Appendix IV: Optimization Matrix Tables Used to Determine Preferred Flows

Yazoo River At Greenwood
Yazoo River At Belzoni
Yazoo River At Yazoo City

Species	3000	4000	5000	6000	7000	8000	9000	10000	15000
	Discharge (cfs) WUA								
Buffalo	6754	7344	6650	5791	5300	2224	2450	2393	4660
Carp	4704	8964	7050	5111	4650	3763	2750	2315	4079
Channel Catfish	3653	7309	6400	5208	5250	5223	2975	2419	4366
Blacktail Shiner	10790	14874	12665	10944	10400	9795	8950	8864	7544
Minimum WUA Value in Column	3653	7309*	6400	5111	4650	2224	2450	2315	4079
White Crappie	363	739*	370	143	130	78	80	228	461

* Highest WUA in row that corresponds to the preferred flow.

Tallahatchie River Near Swan Lake

Species	3000	4000	5000	6000	7000	8000	9000	10000	15000
	Discharge (cfs) WUA								
Buffalo	4045	4071	5155	5536	8181	7185	7250	7262	2152
Carp	4807	4635	7162	6754	13581	12424	9800	6025	1246
Channel Catfish	5551	5230	8630	9416	13860	14084	12505	4493	1264
Blacktail Shiner	11988	12183	10632	7080	6949	5961	5100	2420	1041
Minimum WUA In Column	4045	4071	5155	5536	6949	5961	5100	2420	1041
White Crappie	231	276	788	870	1573	624	500	215	12

Big Sunflower River Near Anguilla

Species	Discharge (cfs) 500	1000	2000	3000	4000	5000	8000
	WUA						
Buffalo	99275	60796	20095	16557	17633	17105	18834
Carp	49933	26707	16950	13804	17857	22931	18521
Channel Catfish	20045	13451	10212	8384	7104	18110	11888
Blacktail Shiner	51560	37075	14403	6301	8140	10320	5719
Minimum WUA In Column	20045	13451	10212	6301	7104	10320	5719
White Crappie	6209	4593	7057	4619	4768	4161	3386

Tallahatchie River Near Lambert
Hickahala Creek Near Senatobia

Species	Discharge (cfs) 400	600	800	1000	5000	10000
	WUA					
Buffalo	6688	5688	4891	5386	10450	7427
Carp	7263	6107	6735	8180	11646	5605
Channel Catfish	8650	7131	8437	9838	6708	3853
Blacktail Shiner	30823	20885	16536	13310	3349	2149
Minimum WUA In Column	6688	5688	4891	5386	3349	2149
White Crappie	204	407	431	936	2555	961

Steele Bayou Near Onward
Coldwater River Near Sarah
Big Sunflower River At Sunflower
Little Tallahatchie River At Etta

Species	Discharge (cfs) 50	100	200	400	600	800	1000	2000	3000	5000
	WUA									
Buffalo	82261	82874	77582	67568	56899	44263	33497	6944	3535	2814
Carp	54729	50737	43927	36290	25685	18136	12715	4995	3419	1107
Channel Catfish	20815	19174	18291	15443	12339	9174	6089	3782	1709	433
Blacktail Shiner	39643	40879	47688	26395	16844	11772	7680	2034	710	470
Minimum WUA In Column	20815	19174	18291	15443	12339	9174	6089	2034	710	433
White Crappie	54773	34479	10166	8188	1957	1076	676	332	124	0

Deer Creek Near Hollandale
Yalobusha River At Calhoun City
Yocona River Near Oxford

Skuna River At Bruce
Coldwater River Near Lewisburg
Big Sunflower At Clarksdale

Species	Discharge (cfs) 10	50	100	200	400	600	800	1000
	WUA							
Buffalo	5230	8929	13537	30239	30335	20516	13314	9920
ırp	3554	11615	16836	30265	19484	7472	4111	2837
Channel Catfish	4429	14016	18857	26377	6634	1976	1124	524
Blacktail Shiner	12095	23326	32303	27644	7748	1988	771	374
Minimum WUA In Column	3554	8929	13537	26377	6634	1976	771	374
White Crappie	404	881	1997	9205	3091	1940	955	603

END

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